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The Influence of Anxiety on Visual Attention in Climbing

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The object of the current study was to investigate anxiety-induced changes in movement and gaze behavior in novices on a climbing wall. Identical traverses were situated at high and low levels on a climbing wall to manipulate anxiety. In line with earlier studies, climbing times and movement times increased under anxiety. These changes were accompanied by similar changes in total and average fixation duration and the number of fixations, which were primarily aimed at the holds used for climbing. In combination with these findings, a decrease in search rate provided evidence for a decrease in processing efficiency as anxiety increased.

Keywords: gaze behavior, efficiency, movement behavior, attentional control theory

In sport psychology, anxiety is generally accepted as an unpleasant emotion likely to arise when individuals doubt their ability to cope with external or internal demands (Woodman & Hardy, 2001). This is reflected in the broad definition of anxiety that is given by Schwenkmezger and Steffgen (1989): "Anxiety can be regarded as a broad concept for a number of very complex emotional and motivational states and processes that occur as a result of threat. This threat is related to the subjective evaluation of a situation, and concerns jeopardy to one's self-esteem during performance or social situations, physical danger, or insecurity and uncertainty" (pp. 78–79).

Concerning the effect that anxiety has on sports performance, the influence of attention is often called upon to explain its effects (Beilock & Carr, 2001; Janelle, Singer, & Williams, 1999; Moran, Byrne, & McGlade, 2002; Nideffer, 1976, 1989; Pijpers, Oudejans, Bakker, & Beek, 2006; Wilson, Smith, Chattington, Ford, & Marple-Horvat, 2006). A recent account of the mechanisms that are involved in the anxiety–performance relationship is provided by attentional control theory (Eysenck, Derakshan, Santos, & Calvo, 2007), which has recently been developed by Eysenck and his colleagues on the basis of processing efficiency theory (Eysenck & Calvo, 1992). A basic assumption of these theories is that anxiety shifts attention

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away from task-relevant information to task-irrelevant cues, thereby decreasing performance. Thus, it is assumed that increased anxiety will cause individuals to focus on distracting stimuli either externally or internally instead of focusing on task-relevant information. If an individual focuses attention on the crowd, it is very likely that relevant information cannot be picked up. An example of internal distraction is provided by attention to worries (e.g., self-preoccupations, concerns over evaluation, concerns over level of performance) proceeding from, for instance, performance pressure (Eysenck & Calvo, 1992; Sarason, 1988; Wine, 1971).

As a theoretical background to the anxiety performance relationship, attentional control theory is generally in line with earlier models of distraction (e.g., Sarason, 1988; Wine, 1971; see also Beilock & Carr, 2001; Eubank, Collins, & Smith, 2000; Eysenck, 1992; Lewis & Linder, 1997; Mullen & Hardy, 2000). Going beyond these models, attentional control theory also provides an explanation for why anxiety does not necessarily have to lead to a decrement in performance. Although worry may tax working memory processing and capacity, the adverse effects of anxiety may be compensated for by a second stream of processes involving increased on-task effort and activities to improve or maintain performance (Eysenck & Calvo, 1992). In this case, efficiency of task execution may be impaired while performance itself remains unharmed or even improves. In other words, using the terminology of attentional control theory, while performance effectiveness may remain unchanged, processing efficiency decreases because anxious individuals need to make more of an effort to obtain that result.

Although attentional control theory and processing efficiency theory are claimed to have most relevance to cognitive task performance (Eysenck & Calvo, 1992; Eysenck et al., 2007), several studies have gained empirical support for the processing efficiency theory with respect to perceptual-motor tasks (Mullen & Hardy, 2000; Mullen, Hardy, & Tattersall, 2005; Murray & Janelle, 2003, 2007; Smith, Bellamy, Collins, & Newell, 2001; Williams, Vickers, & Rodrigues, 2002; Wilson et al., 2006). Given the heavy reliance on visual input for decision making and response planning in most sports, several of these researchers have recently started to investigate how visual cues are differentially identified and processed when performers are anxious (e.g., Janelle et al., 1999; Murray & Janelle, 2003; Williams & Elliott, 1999; Williams et al., 2002; Wilson et al., 2006). Although the results of these studies are certainly promising (Janelle, 2002), a comprehensive description of the precise changes in gaze behavior when individuals perform under anxiety does not yet exist. Therefore, in the current study we wished to extend this line of research by combining the measurement of visual search variables with the measurement of movement variables in a group of participants executing a complex whole-body task in a real-life setting.

Direct leads to this approach are recent investigations by Pijpers and his colleagues (Pijpers, Oudejans, & Bakker 2005; Pijpers et al., 2006), who studied anxiety-induced changes in movement behavior. Pijpers et al. (2005) had participants climb a horizontal traverse low and high on a climbing wall, and observed, among other things, movement variables such as climbing time, the time spent grasping holds, and the time spent executing hand and foot movements. In line with the expectations, participants showed longer climbing times, grasped holds longer, and showed slower movements when performing in the high-anxiety condition, high on the wall.

In a follow-up study, Pijpers et al. (2006) investigated participants' actual and perceived maximum overhead reaching height and the number of performatory (i.e., actual) and exploratory movements that participants executed. In line with their expectations, participants showed a decrease in perceived as well as actual maximum reaching height, and executed more movements in the high anxiety condition. However, the extra number of holds that participants used to climb in the high-anxiety condition implied a decrease in reaching ability that was larger than could be expected on the basis of the observed results in actual maximum reaching height. According to the authors, this indicated that on top of the observed changes in maximum reaching height, anxiety might also have induced changes in the ability to detect relevant information needed for climbing (i.e., visual attention). This was tested in a third experiment, in which participants were asked to detect lights that were projected around them on the climbing wall while they were climbing. As participants detected significantly fewer lights in the high-anxiety condition, it was concluded that in the high-anxiety condition, attention was more narrowly focused on information relevant for climbing, whereas information that was less relevant for climbing at that moment (i.e., projected lights) was overlooked.

When viewed from the perspective of attentional control theory (Eysenck et al., 2007), one could contend that the longer climbing times and greater numbers and durations of movements that Pijpers et al. (2005, 2006) found in their studies, in fact, indirectly indicate a decrease in processing efficiency as anxiety increased. Namely, although participants still managed to perform the climbing task, they had to apply additional resources (e.g., longer climbing times and movement durations) and activities (e.g., more movements) to achieve this (i.e., efficiency decreased). It is possible that the additional effort invested also included the allocation of more attentional resources to primary task execution, thus leaving less attentional capacity to detect the peripheral lights. An analysis of visual search data, as suggested by Pijpers et al. (2006), would provide more direct insight into processes underlying the apparent loss of movement efficiency (i.e., gaze behavior and visual attention; Eysenck & Calvo, 1992; Eysenck et al., 2007).

Using the same experimental setting as Pijpers et al. (2005, 2006), and adding to their results on movement behavior, it was our primary aim in this study to determine and describe anxiety-induced changes in visual attention by analyzing participants' gaze behavior while they are climbing on a climbing wall. Generally, we expect our results on movement behavior to be in line with those of Pijpers et al. (2005, 2006). This means that with anxiety, participants will show increases in their climbing time and the duration and number of their movements. Furthermore, and in line with attentional control theory (Eysenck et al., 2007), we expect that changes in movement behavior will be accompanied by changes in gaze behavior, reflecting increases in effort to maintain primary task execution. More specifically, we expect increases in duration and number of fixations on task-relevant locations such as handholds, suggesting additional investment of attentional resources. This would provide further indications of decreased processing efficiency when suffering from anxiety.

Methods

Participants

A total of 12 participants (7 males, 5 females) with a mean age of 24.4 years (*SD* = 1.98), volunteered to participate in the experiment. The participants—either university students ($n = 9$) or recently graduated ($n = 3$)—had no particular experience with climbing, they had a mean height of 1.81 m (*SD* = 0.09), had normal vision (i.e., they did not wear glasses or contact lenses), and were naïve to the purpose of the experiment. Permission of the institutional ethics committee was obtained and all participants provided informed consents. Earlier findings by Pijpers et al. (2005, 2006) showed that there was no need to treat male and female participants as separate groups in the current setting.

The Dutch version of the A-Trait scale of the State-Trait Anxiety Inventory (STAI) was used as a standard check to measure trait anxiety (Spielberger, Gorsuch, & Lushene, 1970; Van der Ploeg, Defares, & Spielberger, 1979). The mean trait anxiety score for the participants was 32.0 (*SD* = 4.32; comparable to earlier results that were obtained with university students by Pijpers et al., 2005, 2006), implying that the participants had no particular tendency to respond across many situations with high levels of state anxiety.

Experimental Setup

The participants climbed on a vertical climbing wall (width: 3.5 m, height: 7.0 m), which was set up in a large experiment room. The wall consisted of nine laminate panels with a gray grainy texture for traction. Two identical horizontal routes (so-called traverses) were built on high and low levels on the wall to provide two different anxiety conditions (i.e., high and low anxiety). The mean height of the footholds in the low traverse (low-anxiety condition) was 0.44 m. The mean height of the footholds in the high traverse (high-anxiety condition) was 4.25 m. For the purpose of the experiment, numerous holds were placed on the wall. Both traverses consisted of 26 hand- and footholds, whereas in earlier experiments (Pijpers, Oudejans, Holsheimer, & Bakker, 2003) it was shown that a similar distance could easily be climbed by inexperienced climbers using only 11 holds. Four holds on the right side of the traverse were marked as the starting position, and four holds on the left side indicated the finishing position (see Figure 1).

To enable the participants to climb in the high condition, a large stepladder was used to reach the climbing wall. This stepladder had a small platform that allowed participants to rest after having climbed it, ensuring that they started climbing the high traverse in the same physical condition as the low traverse. Participants wore good fitting climbing shoes (Enduro 954, La Sportiva) and—in both conditions—they also wore a climbing harness (Singing Rock). To ensure the safety of the participants the "top-roping" technique was used (Skinner & McMullen, 1993). When properly applied, the top-roping technique reduces the risk of a fall to nearly zero.

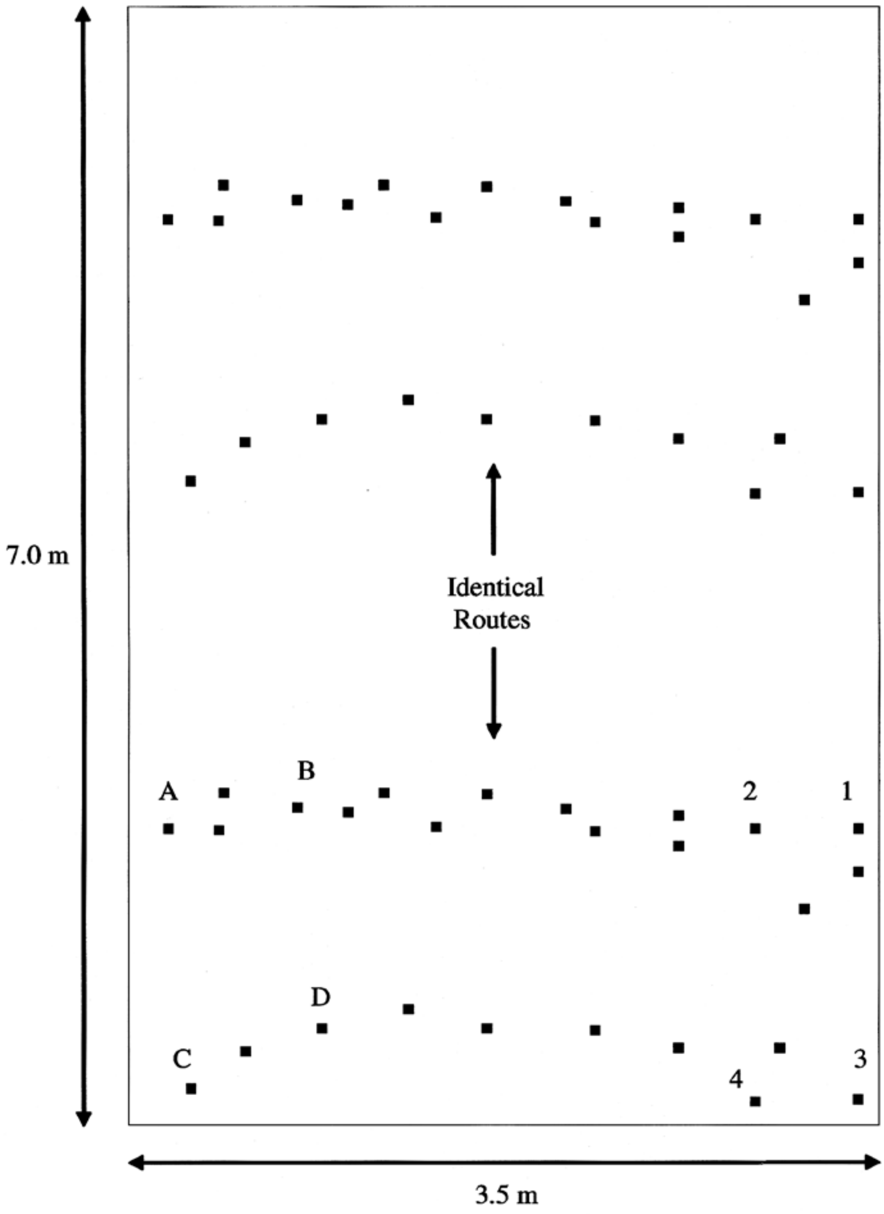

Figure 1 — Front view of the climbing wall. Black squares indicate the positions of the hand- and footholds. Holds 1–4 indicate the starting position; holds A–D indicate the finishing position.

Data Collection

To track the participants' eye movements and to analyze their gaze-location during the climbing task, an Applied Systems Laboratories eye-tracking device (Model 501, referred to as ASL in what follows) was used. The ASL is a monocular, corneal reflection system that measures individuals' fixation location by using a headband mounted eye and scene camera. Using the video images that are made by the eye camera, the relative position of the pupil and the corneal reflex is used to compute eye movements and line of gaze. These data were processed by a personal computer and superimposed as a small black square on the scene monitor to indicate the participants' gaze location. The ASL has an accuracy of approximately 1° of the visual angle and allows measurement of gaze location within an angle of about 45° in the vertical plane and 50° in the horizontal plane. In the current experiment, with participants climbing very close to the wall, this limited our measurement to an area surrounding only the handholds that appeared in the participants' climbing direction. The sampling frequency of the ASL is 50 Hz. A 27-m-long cable was attached to the helmet and carried by the participants through a waist belt to enable measurement under comparable conditions in the high and low condition.

In both conditions, the participants' movement behavior was captured by a movement camera (digital camcorder with a sampling rate of 50 Hz) that was positioned at a distance of 5.0 m from the climbing wall. To allow simultaneous assessment of movement behavior and fixation location, the sampling frequency of the movement camera was synchronized with the ASL by using a synchronization device that was purpose-designed at our faculty, specifically for the current experiment. This synchronization device also provided a standardized time code that was used in the analysis of the data.

State anxiety was assessed by using the "anxiety thermometer" validated by Houtman and Bakker (1989) and successfully used in earlier experiments by Pijpers et al. (2003, 2005, 2006). The anxiety thermometer is a 10-cm continuous scale on which participants were asked to rate their feelings of anxiety at a particular moment in time, ranging from 0 (i.e., *not anxious at all*) on the left end to 10 (i.e., *extremely anxious*) on the right end. Participants had to place a cross on the scale to indicate how anxious they felt. The distance (in centimeters) between the left end (0) and the cross was used to measure the reported anxiety. The validity and test–retest reliability of the anxiety thermometer are fair, with correlation coefficients ranging between .60 and .78 (Houtman & Bakker, 1989). Other than with the STAI A-State scale (Spielberger et al., 1970) and the CSAI-2 (Martens, Vealey, & Burton, 1990), which are used in many other studies, the anxiety thermometer allows for a very quick assessment of state anxiety. It should be noted that the anxiety thermometer does not distinguish between cognitive and somatic anxiety as does the CSAI-2, and, for instance, Krane's (1994) mental readiness form (MRF). Nevertheless, anxiety thermometer scores appear to correlate equally with cognitive and somatic anxiety scores on the CSAI-2, with correlation coefficients of .59 and .62, respectively (Bakker, Vanden Auweele, & Van Mele, 2003). Taking all this into account, the anxiety thermometer was considered an appropriate measure of state anxiety and ideal for the purposes of the current study. For each measurement, a separate anxiety thermometer was used.

During the assessments, participants' heart rate values were recorded every 5 s by using a Sporttester (Polar Electro 3000). Afterward, the recorded values were used to calculate the participants' mean heart rate for each condition.

Procedure

Participants were tested individually on a single day. In total, measurements lasted about 1 hr. Participants were informed about the procedure of the experiment and then asked to read and sign an informed consent statement. After that, they completed the Dutch version of the STAI A-Trait scale (Van der Ploeg et al., 1979).

Each participant was fitted with climbing shoes and a harness, as well as a Sporttester. Next, the ASL system was adjusted to fit the participant's head, and calibrated to ensure that it was registering the participant's line of gaze as accurately as possible. In the calibration procedure, participants were asked to fixate nine predetermined points on a calibration grid, one at a time. As soon as a calibration point was fixated, the experimenter pressed a key on the computer that automatically calculated the calibration coefficients. The calibration coefficients were tested—and adjusted when necessary—while participants were allowed to practice climbing on the climbing wall.

After practicing, the participants were briefed in detail about the climbing task and explicitly informed about the fact that both traverses (high and low) were identical. Using a counterbalanced design, participants were told to climb either the high or the low traverse in their own tempo, starting from the starting position (i.e., on the right end of the climbing wall, see Figure 1) and ending in the finishing position (i.e., on the left end of the climbing wall, also see Figure 1), and ensuring that while they were climbing they felt as safe as possible (in the high condition, participants first climbed the stepladder before this instruction was given). After the instruction, participants imagined themselves climbing the particular traverse and filled out an anxiety thermometer to anticipate how anxious they thought they would feel while climbing. Subsequently, participants were asked to take position on the wall and heart rate recording was started. Proper recording of the ASL and movement camera was checked, and climbing started as soon as the experimenter gave a starting signal. After having reached the finishing position, heart rate recordings were ended, participants stepped down from the wall (either on the ground or on the step ladder), and filled out a second anxiety thermometer to indicate how anxious they had felt while climbing. After this, a break of approximately 5 min was taken (longer when necessary) before continuing with the other traverse.

During the climbing task, one of the experimenters served as belayer. In the low condition, the belayer acted so as to ensure that both conditions were similar for the climber. Before climbing the low traverse, however, participants were informed that if they slipped they should break their fall themselves, as the safety procedure would not be effective at that climbing height. During the experiment, none of the participants fell or slipped in any of the conditions.

Data Analysis and Dependent Variables

Raw data from the ASL and movement camera were analyzed frame by frame on a personal computer by the first author, using a video analysis program (Adobe

Premiere 6.5). To provide a measure of reliability, the data of four participants were reanalyzed by the second author, which rendered an interrater reliability score of .94. Which particular holds were used or gazed at could be determined from the video recordings. As the exact locations of these holds were known, distances between holds could be readily computed. The minimum duration of a fixation was set at 100 ms, corresponding to five frames of the video data (Vickers, 1992). Regarding the participants' movement behavior, variables that were determined included total climbing time, time spent standing still, total time moving with hands and feet, number of movements, and average movement duration from one hold to the next (Pijpers et al., 2005, 2006).

Concerning the participants' gaze behavior, visual inspection of the video recordings rendered four different fixation locations: (a) handholds, (b) hands, (c) wall, and (d) "other." Furthermore, a distinction was made between fixations that were executed in direct combination with the participants' hand movements (i.e., performatory fixations) and fixations that were executed when participants were not moving to a new handhold (i.e., exploratory fixations). Variables that were determined included fixation duration, number of fixations, and average fixation duration in total, per fixation location, and per fixation type (cf. Janelle, 2002; Janelle et al., 1999; Moran et al., 2003; Murray & Janelle, 2003; Williams & Elliott, 1999; Wilson et al., 2006). Furthermore, search rate was calculated by dividing the total number of fixations that participants executed by the total duration of fixations across all fixation locations (Janelle et al., 1999). Similarly, using our combined measurement of movement behavior and gaze behavior, the participants' mean distance of fixations and mean distance of hand movements were calculated per condition, with movement distance being the distance between the two handholds between which participants were moving and fixation distance the distance between the handhold that participants gazed at and the leftmost handhold that participants were holding during that fixation.

For each participant, the anxiety scores for the low and high conditions were calculated by taking the mean anxiety score from the anxiety thermometers that the participants filled out before and after climbing. The low and high conditions were compared using one-tailed paired *t* tests or one-way MANOVAs depending on the dependent variables in question. Significant multivariate effects were evaluated through follow-up univariate ANOVAs. Effect sizes (Cohen's *f*) were calculated by taking the square root of the ratio of the eta-squared values and the difference between 1.0 and the eta-squared values. Effect sizes of 0.2 or less, about 0.3, and 0.4 or more, represented small, moderate, and large differences, respectively (Cohen, 1988). For the *t* tests, effect sizes (*ES*) were calculated by taking the ratio of the difference between the two means and the mean-within-cell standard deviation of the means (Mullineaux, Bartlett, & Bennett, 2001; Thomas & Nelson, 1996). Effect sizes of 0.2 or less, about 0.5, and 0.8 or more, represented small, moderate, and large differences, respectively (Cohen, 1988).

Results

State Anxiety and Heart Rate

To determine changes in the participants' state anxiety as measured by the anxiety thermometer and mean heart rate values, we employed a one-way MANOVA with repeated measures for height (low vs. high). The test revealed a significant multivariate effect of height, Wilks's $\Lambda = .208$, $F(2, 10) = 19.05$, $p < .001$, $f = 1.95$. Follow-up analyses yielded significant main effects of height on both measures, $F(1, 11) = 31.81$, $p < .001$, $f = 1.70$, and $F(1, 11) = 26.79$, $p < .001$, $f = 1.56$, respectively. Participants showed an increase in their anxiety scores from the low condition ($M = 1.2$, $SD = 0.81$) to the high condition ($M = 4.9$, $SD = 2.25$) and also in their mean heart rate value (HR-low = 114.6 bpm, $SD = 13.00$; HR-high = 127.9 bpm, $SD = 14.11$). Collectively, the results from both anxiety measures showed that participants were more anxious in the high condition than in the low condition.

Movement Behavior

Table 1 presents an overview of the dependent movement variables (time, number, and average duration) for the low- and the high-anxiety condition. As can be seen, there is an increase in most of the reported variables from the low- to high-anxiety condition. To find out which differences were statistically significant, we performed separate *t* tests for climbing time, number of movements, and average movement duration. Given the interdependency of time spent standing still and time spent moving, we analyzed these variables using a one-way MANOVA with repeated measures on height. Similarly, variables relating to hand and foot movements were also analyzed using a one-way MANOVA with repeated measures on height.

Climbing Time. Climbing time was significantly higher in the high compared with the low condition, $t(11) = 5.76$, $p < .001$, $ES = 1.28$, just as time spent standing still and time spent moving (with hands and feet), Wilks's $\Lambda = .252$, $F(2, 10) = 14.86$,

Table 1 Total Climbing Time (s), Time Spent Standing Still (s), Time Spent Moving With Hands and Feet (s), Number of (Hand and Foot) Movements, and Average Duration (ms) of (Hand and Foot) Movements in the High- and Low-Anxiety Conditions

	Condition			
	Low anxiety		High anxiety	
Variable	*M*	*SD*	*M*	*SD*
Climbing time**	29.4	4.79	45.5	12.84
Time spent standing still**	15.2	4.09	28.4	10.79
Time spent moving hands and feet*	14.3	1.98	17.1	3.18
Hand movements*	5.7	0.82	7.0	1.59
Foot movements	8.6	1.71	10.2	2.41
Number of movements**	21.6	2.91	24.5	3.50
Hand movements*	10.3	1.35	12.6	2.31
Foot movements	11.3	2.15	11.9	2.15
Average movement duration	674	145	704	112
Hand movements	564	137	562	97
Foot movements	778	173	864	165

*$p < .05$, **$p < .01$.

$p < .005$, $f = 1.72$, for the multivariate effect, and $F(1, 11) = 32.51$, $p < .001$, $f = 1.72$, and $F(1, 11) = 8.68$, $p < .05$, $f = .89$, for time spent standing still and time spent moving, respectively. The analysis of duration of hand and foot movements at different heights also revealed a significant multivariate effect of height, Wilks's $\Lambda = .524$, $F(2, 10) = 4.53$, $p < .05$, $f = .95$, but the follow-up univariate ANOVAs revealed that only the duration of hand movements was significantly longer in the high compared with the low condition, $F(1, 11) = 6.79$, $p < .05$, $f = .79$.

Number of Movements. The total number of movements that participants executed was significantly higher in the high condition, $t(11) = 3.55$, $p < .001$, ES = .84. The MANOVA on the number of hand and foot movements revealed a significant multivariate effect of height, Wilks's $\Lambda = .462$, $F(2, 10) = 5.82$, $p < .05$, $f = 1.08$. Again, follow-up analyses clearly showed that only the number of hand movements was significantly higher in the high compared with the low condition, $F(1, 11) = 9.63$, $p < .05$, $f = .94$.

Average Movement Duration. Generally, the average duration of the participants' movements did not show significant differences between both conditions, $t(11) = .99$, $p > .05$. The one-way MANOVA with repeated measures for height that was used to analyze the average duration of hand and foot movements did not yield a significant multivariate effect of height.

Gaze Behavior

Table 2 presents an overview of the dependent visual search variables in the low and the high condition. As can be seen, it appears that the observed increases in climbing time and changes in movement behavior (see Table 1) were accompanied by similar changes in gaze behavior. To examine which differences were statistically significant, we performed separate *t* tests for total fixation durations, number of fixations, and average fixation durations. Given the interdependency of gaze behavior to each of the specific locations (handholds, hands, and wall), the three dependent variables fixation duration, number of fixations, and average fixation duration to these locations were collapsed into three separate one-way MANOVAs with repeated measures on height. Similarly, three MANOVAs were also executed on the different types of fixation (i.e., performatory and exploratory).

Total Fixation Duration. The participants' total fixation duration was significantly higher in the high compared with the low condition, $t(11) = 3.99$, $p < .001$, $ES = 1.06$. The MANOVA on the time that participants' spent fixating on each of the locations (i.e., handholds, hands, and wall) revealed a significant multivariate effect of height, Wilks's $\Lambda = .410$, $F(3, 9) = 4.26$, $p < .05$, $f = 1.19$. The follow-up analyses yielded significant main effects of height on the total duration of fixations on handholds, $F(1, 11) = 11.65$, $p < .01$, $f = 1.03$, and on the wall, $F(1, 11) = 4.96$, $p < .05$, $f = .67$, but not on the hands. The total durations of fixations of a specific type (i.e., performatory and exploratory fixations) were both significantly longer in the high than in the low condition, Wilks's $\Lambda = .400$, $F(2, 10) = 7.49$, $p < .05$, $f = 1.22$, for the multivariate effect, and $F(1, 11) = 6.47$, $p < .05$, $f = .77$, and $F(1, 11) = 14.13$, $p < .01$, $f = 1.13$, for performatory and exploratory fixations, respectively.

Table 2 Total Duration of Performatory and Exploratory Fixations on Each of the Distinguished Locations (s), Number of Performatory and Exploratory Fixations on Each of the Distinguished Locations, and Average Duration of Performatory and Exploratory Fixations on Each of the Distinguished Locations (ms) in the High- and Low-Anxiety Conditions

Variable	Condition			
	Low anxiety		High anxiety	
	M	*SD*	*M*	*SD*
Total fixation duration**	7.8	2.16	12.4	4.82
Handholds**	6.6	2.07	10.1	4.36
Hands	0.3	0.5	0.5	0.67
Wall*	0.5	0.56	1.3	1.25
Other	0.5	0.84	0.6	1.74
Total duration of performatory fixations*	4.2	1.69	5.9	2.92
Total duration of exploratory fixation**	3.6	1.26	6.6	3.31
Number of fixations**	21.9	4.31	31.5	11.26
Handholds**	16.8	3.43	23.8	8.93
Hands	1.1	1.24	1.3	1.44
Wall*	2.3	2.14	4.8	3.33
Other	1.8	3.11	1.5	3.09
Number of performatory fixations	6.9	1.38	8.2	2.55
Number of exploratory fixation**	15.0	4.88	23.3	10.22
Average duration of fixations*	359	83	401	62
Handholds	392	109	430	64
Hands	204	109	355	369
Wall	229	91	229	117
Other	244	163	278	158
Average duration of performatory fixations*	603	194	719	165
Average duration of exploratory fixations	243	43	278	47

*$p < .05$, **$p < .01$.

Number of Fixations. The total number of fixations that participants executed was significantly higher in the high than in the low condition, $t(11) = 3.63, p < .001, ES = .99$. The MANOVA on the number of fixations on each of the locations yielded a significant multivariate effect of height, Wilks's $\Lambda = .348$, $F(3, 9) = 5.62, p < .05, f = 1.37$. Follow-up analyses revealed that the number of fixations on handholds, $F(1, 11) = 10.83, p < .01, f = .99$, as well as on the wall, $F(1,11) = 7{,}94, p < .05, f = .85$, but not on the hands, was significantly higher in the high condition. The MANOVA on the number of fixations of a specific type also yielded a significant multivariate effect of height, Wilks's $\Lambda = .451$, $F(2, 10) = 6.09, p < .05, f = 1.10$. This effect could only be confirmed for exploratory fixations, $F(1, 11) = 12.97, p < .005, f = 1.09$, and not for performatory fixations, implying that the number of exploratory fixations increased significantly from the low to the high condition.

Average Duration of Fixations. The average duration of participants' fixations showed a slight, but significant increase, $t(11) = 1.84, p < .05, ES = .40$. There were insufficient data points owing to the fact that not every participant executed fixations to each of the locations in both conditions, so the MANOVA for the average duration of fixations on each of the locations could not be executed. The MANOVA on the average duration of performatory and exploratory fixations, however, yielded a significant multivariate effect of height, Wilks's $\Lambda = .367, F(2, 10) = 8.64, p < .01, f = 1.31$, which was mainly due to significant increases in the average duration of performatory fixations, $F(1, 11) = 5.66, p < .05, f = .72$.

Remaining Variables

On top of the variables presented in Tables 1 and 2, we also analyzed search rate and average movement and fixation distances. To assess the effects of height on the participants' search rate, a paired-samples *t* test was executed. The analysis revealed that the participants' search rate was significantly lower in the high condition ($M = 2.6, SD = 0.45$) than in the low condition ($M = 2.9, SD = 0.64$), $t(11) = 2.05, p < .05, ES = 0.58$.

Average movement and fixation distances were analyzed using a one-way MANOVA with repeated measures on height, which yielded a significant multivariate effect, Wilks's $\Lambda = .492, F(2, 10) = 5.16, p < .05, f = 1.02$. Follow-up analyses revealed that participants only showed a significant decrease in their movement distance from 57.6 cm ($SD = 5.05$) in the low condition to 52.5 cm ($SD = 4.83$) in the high condition, $F(1, 11) = 10.54, p < .01, f = 0.98$. The participants' mean fixation distance did not differ significantly between the low ($M = 40.8$ cm, $SD = 8.36$) and the high condition ($M = 39.5$ cm, $SD = 6.90$), $F < 1$, *ns*.

Discussion

The primary aim of the current study was to determine and describe anxiety-induced changes in movement behavior and visual attention by analyzing climbing and gaze behavior while participants were climbing on a climbing wall. Generally, our results provide a comprehensive overview of the precise changes and parallels in gaze and movement behavior when climbing with anxiety (Tables 1 and 2). In line with our expectations, participants showed longer climbing times, spent more time standing still (i.e., grasped holds longer), spent more time moving hands and feet, and executed more movements in the high-anxiety condition than in the low-anxiety condition. Matching the observed changes in movement behavior, participants looked longer (i.e., showed a significant increase in their total fixation duration), and showed significant increases in the number and average duration of fixations.

Regarding movement behavior, our results replicate the findings by Pijpers et al. (2005, 2006) showing how consistent anxiety influences movement behavior in the current setting. Furthermore, although participants still managed to perform the climbing task, they had to apply additional resources and activities to achieve this, as evidenced by longer climbing times, longer grasping of holds, and more movements. These changes show that movement behavior became less efficient, providing an indirect indication that processing efficiency also decreased under anxiety (Eysenck & Calvo, 1992; Eysenck et al., 2007).

Concerning gaze behavior, our results are generally in line with earlier findings by Janelle et al. (1999), Murray and Janelle (2003), Moran et al. (2002), Williams and Elliott (1999), Williams et al. (2002), and Wilson et al. (2006), who also found more and longer fixations with anxiety. Furthermore, consistent with findings by Murray and Janelle (2003) and Williams and Elliott (1999), the average duration of (performatory) fixations showed a slight but significant increase. As most of the fixations were still directed at handholds, these findings show that with increased levels of anxiety, participants spent more time fixating locations relevant for the climbing task (Eysenck et al., 2007). This also points to the investment of additional attentional resources, and thus, increases in effort to maintain primary task execution. However, changes in gaze behavior for the most part matched the observed increases in climbing time (see Table 1). Unless participants closed their eyes, increases in climbing time should logically be reflected in longer looking. Therefore, to draw conclusions about processing efficiency it is necessary to also examine the ratio between the number of fixations and the total duration of fixations, that is, the search rate (Janelle et al., 1999). Because there was no need to monitor peripheral locations, the decrease in search rate that was found (i.e., less fixations per second) seems to indicate that participants needed more time to extract relevant information from the handholds when they were anxious compared with when they were not anxious. This is an indication of a decrease in processing efficiency as anxiety increased (Eysenck & Calvo, 1992; Eysenck et al., 2007).

Furthermore, the significant decrease in the mean distance of hand movements that we found is consistent with the finding by Pijpers et al. (2006) that perceived (as well as actual) maximal reaching distance decreased with anxiety. Because there was no decrease in mean distance of fixations with anxiety, we can now conclude that the use of more (nearby) holds was not due to not having seen the holds that were further away. Possibly, a decrease in processing efficiency led anxious participants to generally prefer handholds that were closer over handholds that were further away despite the fact that they visually explored the same handholds as without anxiety.

Finally, concerning our analysis of fixations of a specific type (i.e., performatory and exploratory fixations), it should be noted that the average duration of performatory fixations appeared to be almost three times as long as the average duration of exploratory fixations (see Table 2). On the other hand, participants generally executed two to three times as many exploratory fixations as performatory fixations. These findings reflect some of the perceptual differences that exist between executive actions (supported by performatory fixations) and information-gathering actions (supported by exploratory fixations; Gibson, 1988). In short, the analysis of the type of fixations revealed the importance of distinguishing performatory and exploratory fixations when investigating gaze behavior during the execution of a movement task.

To summarize, the current study provides a comprehensive overview of the precise changes in gaze and movement behavior when performing under anxiety. As far as we know, this is one of the first studies combining the measurement of gaze behavior with that of movement behavior. We found that the increases in number and total duration of movements were matched by increases in the number, total duration, and average duration of fixations. In combination with these findings, a decrease in search rate provided clear indications of a decrease in processing efficiency as anxiety increased.

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